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Reinventing machines: the transmission history of the Leibniz calculator

FLORIN-STEFAN MORAR*

Abstract. This paper argues that we should take into account the process of historical transmission to enrich our understanding of material culture. More specifically, I want to show how the rewriting of history and the invention of tradition impact material objects and our beliefs about them. I focus here on the transmission history of the mechanical calculator invented by the German savant Gottfried Wilhelm Leibniz. Leibniz repeatedly described his machine as functional and wonderfully useful, but in reality it was never finished and didn't fully work. Its internal structure also remained unknown. In 1879, however, the machine re-emerged and was reinvented as the origin of all later calculating machines based on the stepped drum, to protect the priority of the German Leibniz against the Frenchman Thomas de Colmar as the father of mechanical calculation. The calculator was later replicated to demonstrate that it could function 'after all', in an effort to deepen this narrative and further enhance Leibniz's computing acumen.

During the sixteenth and seventeenth centuries, savants and literati with mixed mathematical inclinations were keenly interested in simplifying and automating calculation. This goal was something that unified the interests of two very different groups: mathematicians or astronomers engaged in the social-credit business of the *commercium literarium* on the one hand, and shopkeepers, apothecaries and accountants preoccupied with the real-money business of burgeoning global capitalism on the other. In this context, calculating systems such as Napier's rabdology or Samuel Morland's cyclology emerged as paper- and wood-based solutions to these rather pesky problems of mathematical knowledge.[1] Morland's and Napier's instruments, however, were not fully

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1 See John Napier, *Mirifici logarithmorum canonis descriptio*, Edinburgh: Ex officinâ Andreæ Hart bibliopôlæ, 1614; also Napier, *Rabdologiæ, Seu Numerationis per Virgulas Libri Duo Cum Appendice de Expeditissimo Multiplicationis Promptuari*, Edinburgh: Excudebat Andreas Hart, 1617. For Morland see Samuel Morland and Humphry Adamson, *A New and Most Useful Instrument for Addition and Subtraction of Pounds, Shillings, Pence, and Farthings: Without Charging the Memory, Disturbing the Mind, or Exposing the Operator to Any Uncertainty : Which No Method Hitherto Published, Can Justly Pretend to*, London?: s.n.,

automatic calculating systems. Even though effective, they were merely aids to speeding up the execution of mathematical operations. They also required specialized knowledge and some training. It is only with the calculatrice of Blaise Pascal that moving metal cogs were made to bear the brunt of simple mathematics. The so-called Pascaline promised the complete black-boxing of basic arithmetic; the only knowledge required being that of the numbers to be inputted. This machine ultimately worked only for addition and subtraction, but it greatly enhanced Pascal's status and caused ripples in the European correspondence networks of the time.[2]

The young and patronless Gottfried Wilhelm Leibniz, living in the 1670s in Mainz, was at the receiving end of these ripples.[3] He saw in Pascal's calculatrice an excellent reason to solidify his correspondence with Louis XIV's librarian, Pierre de Carcavy. Carcavy had access to one of the models of the machine and was also well connected with Colbert, the Sun King's powerful finance minster. In June 1671, Leibniz wrote to Carcavy to inquire how the Pascaline worked, suggesting that he was able to build an even better instrument, for all four mathematical operations. Seeing how much this project enhanced Pascal's standing, he was sure Colbert would extend to him the same honours: a patent and maybe even a position at the Académie royale des sciences.[4] Barely arrived in Paris in 1672, Leibniz saw the Pascaline, understood the way it worked, quickly copied its design and set out to the artisan quarters to produce a new machine which could also multiply and subtract.[5] This project to build a new machine – the Leibnizian Überpascaline – and, specifically, its transmission history is the topic of this paper.[6]

1672; Samuel Morland, *The Description and Use of Two Arithmetick Instruments: Together with a Short Treatise, Explaining and Demonstrating the Ordinary Operations of Arithmetick : As Likewise a Perpetual Almanack and Several Useful Tables: Presented to … Charles II …*, London: Printed and to be sold by Moses Pitt …, 1673. The most recent work on Morland is J.R. Ratcliff, 'Samuel Morland and his calculating machines *c.*1666: the early career of a courtier–inventor in Restoration London', *BJHS* (2007) 40(2), pp. 159–179. Some of these aids were also made of brass.

2 Blaise Pascal, 'Privilege de la machine arithmetique' in Pascal, *Oeuvres complètes*, vol. 2, Paris: Desclée de Brouwer, 1970, pp. 713–714, 714.

3 For the broader context of Leibniz's life at this time see Maria Rosa Antognazza, *Leibniz: An Intellectual Biography*, Cambridge: Cambridge University Press, 2009, esp. pp. 79–123. Leibniz procured himself during this time a copy of Pascal's *Pensées*. This was probably the source of his knowledge about the Pascaline. Gottfried Wilhelm Leibniz *et al.*, *Sämtliche Schriften und Briefe*, Berlin etc. (Conventionally known as Akademie Ausgabe, here abbreviated AA), I, 1, p. 436.

4 Leibniz based his assumptions on Carcavy's suggestion that he could obtain access to Colbert if he could produce what he called a 'chose réel et solide'. AA (2006 edn) II, 1, p. 308.

5 Carcavy's invitation is recorded in AA (2006 edn), II, 1, p. 208. Evidence of Leibniz's visit in the spring of 1672 is a letter from Carcavy saying, 'Vous pouvez Monsieur, venir quand il vous plaira, mais si vous jugez à propos que ce soit demain du matin je vous attendray, Et ne vous donnerois pas cette peyne si je n'avois des affaires importantes qui m'arrestent a la maison.' AA II, 1, p. 339. When he saw the Pascaline, Leibniz made notes on its design. See Leibniz manuscripts in the Hannover Library XLII, 5, p. 5 (Leibniz Handschriften – here abbreviated LH).

6 There is currently little work on this topic. The most recent incursion is Matthew L. Jones, 'Improvement for profit: calculating machines and the prehistory of intellectual property', in Jessica Riskin and Mario Biagioli (eds.), *Nature Engaged: Science in Practice from the Renaissance to the Present*, Basingstoke: Palgrave Macmillan, 2012, pp. 125–147. See also Jones, *Reckoning with Matter: Calculating Machines, Innovation, and Thinking about Thinking from Pascal to Babbage*, Chicago: The University of Chicago Press, forthcoming

The focus on scientific instruments in the history of science of the early modern period has helped demolish stiff, artificial distinctions between the intellectual and the mechanic, the scholar and the craftsman.[7] Consequently, the separate professional roles of curator and historian of science have been brought closer together, as much as have collections of scientific instruments and departments of the history of science. Scientific instruments from the past are now routinely deployed to project more interesting, materially grounded stories about historical contexts. Without contesting this approach, in this paper I want to propose that the history of transmission of scientific instruments can also be a legitimate object of study, perhaps as much as the already established history of the transmission and circulation of books as material objects is one: just as books are not mere naked conveyors of textual meaning, scientific instruments also are not just stand-ins for the scientific past they are made to convey. Artefacts themselves, as artefacts, have a history of how they got to our present. Consequently, the past that artefacts represent is not always a reflection of their historical origins. It can be a by-product of their transmission.

What I seek to describe here has been noted before by historians of science in connection with the so-called 'stories of discovery'. As both Simon Schaffer and Hans-Jörg Rheinberger have pointed out, scientific discoveries and technological inventions do not have a single moment of genesis and do not align in linear histories.[8] Paradoxically, however, such linear narratives identifying scientific and technological heroes and dramatic moments of discovery are being generated unrelentingly. In lack of a better explanation, Rheinberger proposes that this might be intrinsic to the way science works: research systems constantly produce the future in a way that is disconnected from the past, and, as the future gets produced, because it is unexpected and radically

2014. In German see Ludolf von Mackensen, 'Die Vorgeschichte und die Entstehung der 4-Spezies-Rechenmaschine von Gottfried Wilhelm Leibniz nach bisher unerschlossenen Manuskripten und Zeichnungen mit einem Quellenanhang der Hauptdokumente', PhD dissertation, University of Munich, 1968. This dissertation covers the Paris phase of the development history of the machine, particularly the period 1671–1677. The interpretative line that Mackensen takes is centered on Leibniz's visionary genius, but the dissertation provides important factual information for the period covered. The addendum contains transcriptions of several manuscripts. For the period of time the Leibiz calculator was in Helmstedt under the supervision of Christian Wagner see Ernst Eberhard Wilberg, *Die Leibniz'sche Rechenmaschine und die Julius-Universität in Helmstedt*, Braunschweig: Universitätbibliothek der Technischen Universität Carolo-Wilhelmina, 1977. For the same period but focused on the artisans see Günter Scheel, 'Helmstedt als Werkstatt für die Vervollkommnung der von Leibniz erfundenen und konstruierten Rechenmaschine (1700–1711)', *Braunschweigisches Jahrbuch für Landesgeschichte* (2001) 82, pp. 105–118.

7 J. A. Bennett, curator and historian of science, has been a tireless proponent for collapsing such distinctions. See, for example, J.A. Bennett, 'The mechanics' philosophy and the mechanical philosophy', *History of Science* (1986) 24, pp. 1–28.

8 The origin of these ideas is Thomas Kuhn's 1962 paper 'The historical structure of scientific discovery', *Science* (1962) 136, pp. 760–764. Rheinberger's is the most recent take on the subject. See Hans-Jörg Rheinberger, 'Experimental systems: historiality, narration, and deconstruction', *Science in Context* (1994) 7, pp. 65–81. See also Simon Schaffer, 'Scientific discoveries and the end of natural philosophy', *Social Studies of Science* (1986) 16, pp. 387–420. For other similar work see S.W. Woolgar, 'Writing an intellectual history of scientific development: the use of discovery accounts', *Social Studies of Science* (1976) 6, pp. 395–422. And a compelling case study is Augustine Brannigan, 'The reification of Mendel', *Social Studies of Science* (1979) 9, pp. 423–454.

different, the past is rewritten from its point of view. 'Stories of discovery' have, in this sense, according to Rheinberger, the function and effect of making the present 'the future of a past that never happened'.[9] In this paper, my goal is to show that there is more than meets the eye to these rewritings of the past: the creation of 'a past that never happened' only seems discrete; we can actually study empirically how it gets produced and trace its consequences. In a more general way, I also hope to show that we can produce meaningful answers to questions about how we came to believe what we believe about historical figures such as Leibniz and the materially grounded stories we share publicly about them. In what follows, I will narrate the transmission history of the calculator, tracing its travels in space and in time from the seventeenth century to the twenty-first.

Design and development

As Leibniz came out through the door of Louis XIV's library after seeing the Pascaline, he left behind all of his previous ideas of what a new type of calculator could look like, but not his goals.[10] He had begun thinking about building a machine since at least 1670, two years before he came to Paris, and the challenge was clear: if mortal man had the power to transpose in 'yellow brass' the faculty of mathematical reasoning, there could be no doubt that God had been able to house a 'more general spirit' into the body of animals, giving them life.[11] The calculator could thus serve, at the very least, as another type of argument for the existence of God. But such lofty philosophical and theological ideals could not be reached unless all mathematical operations were successfully put to metal.

Pascal's machine afforded, as Leibniz quickly realized, half of the solution. It could perform additions and subtractions correctly and also carry digits upward, for example from 9 to 10 or from 99 to 100, when adding 1 in each case. What was needed was to attach a mechanism for multiplication and division. Multiplication was, after all, an iterated addition in that the same number had to be added to itself as many times as the multiplier required, and division was the reverse of this process. But how to find a way to store the number to be repeated in the addition/subtraction mechanism, how to count the number of repetitions and how to input easily any desired number? These were the

9 Rheinberger, op. cit. (8), p. 412.

10 According to Mackensen, op. cit. (6), pp. 31–51 and transcriptions 128 ff., the earliest manuscripts from the Mainz period are 'Instrumentum Arithmeticum and Instrumentum panarithmeticon oder die "Lebendige Rechenbank"'. Cf. LH XLII, 5, pp. 15–17. The correct order of the 'Instrumentum arithmeticum' manuscript is pp. 16v, 16r, 15v, 15r.

11 This is one of the more interesting justifications Leibniz found for the machine. The full citation is as follows: 'La machine dont nous donnons icy la description exterieure, fait voir que l'esprit humaine peut trouver le moyen de se transplanter de telle façon dans une matière inanimée qu'il luy donne le pouvoir, de faire bien plus qu'il n'auroit fait lui-même : pour convaincre sensiblement ceux qui ont de la difficulté à concevoir comment le Createur puisse longer une apparence d'esprit un peu plus générale dans les corps des bestes qoyque fourni de tant d'organes ; puisque le loton même a peu recevoir l'imitation d'une opération de la raison qui est à la vérité particulière ou determinée, mais des plus difficiles, veu que les pythagoriciens croyaient de pouvoir par là distinguer l'homme de la beste et de faire entrer dans sa définition la faculté de se servir de nombres.' LH XLII, 5, II, p. 33r.

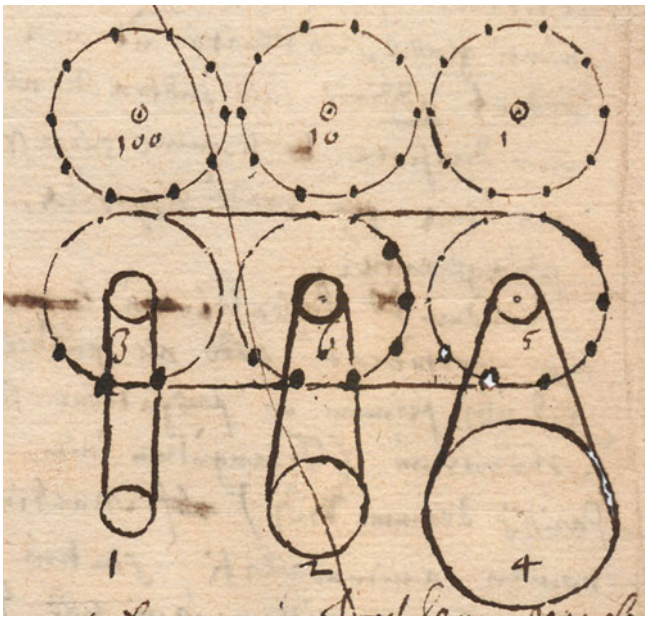

Figure 1. Drawing from Machina arithmetica, LH XLII, 5, p. 1v. GWLB Hannover.

concrete technical questions on which the German savant wasted ink and paper over the next few years.

In 1672 Leibniz drew and described the concept of a mechanism with transmission cords.[12] The top row is supposed to be the Pascaline and the bottom the multiplication machine. The drawing does not intuitively suggest a feasible instrument, but it summarizes the core idea to be implemented. The paradigm is simple: the machine was meant to imitate the order in which mathematical operations are done on paper. Take the case of multiplication. For the example 365×124, which Figure 1 illustrates, one would need to first multiply 365 by 4. The disc of larger diameter labeled here 4 would make all the middle 'multiplicandae' wheels spin 4 times, thus adding 365 to itself just as many times, which results in 1,460. After this, the bottom two rows of the machine would need to be shifted to the left in order to execute the operation 365×20, resulting in 7,300. This would be automatically added over the previous result, obtaining 8,760. Next, another leftward shift would enable the result of 365×100, which again would be added to the previous product, to obtain 45,260, the final result.

In order to embody the concept presented here into 'yellow brass', Leibniz first conceived a wheel with variably extractable teeth – the *roue a dents mobiles*. This component would have been able to load into the Pascaline any number immediately. If, for example, the number 3 was needed, three teeth had to be pulled out. In this way it would have moved the Pascaline component 3 positions, displaying the number 3.

12 LH XLII, 5, pp. 1–4, also 67–69. Transcribed in W. Jordan, 'Die Leibnizsche Rechenmaschine', *Zeitschrift für Vermessungswesen* (1897) 26, pp. 289–315.

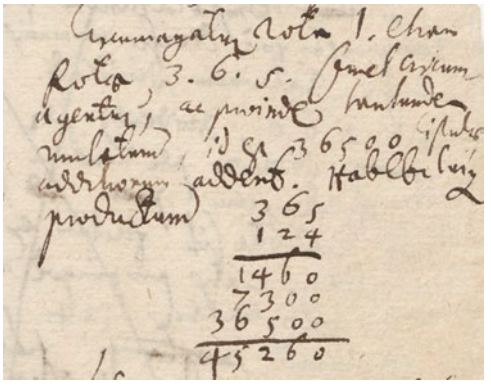

Figure 2. Example of multiplication meant to serve as paradigm for the calculator. LH XLII, 5, p. 4r. GWLB Hannover.

This is the technology illustrated in the manuscript 'Projet de la machine arithmetique', most probably from 1673.[13]

Between 1673 and 1674, in the context of Leibniz's collaboration with Parisian artisans, the wheel with extractable teeth – *roue a dents mobiles* – transformed into what Leibniz called a *roue a dents inégales*. The mechanism was fairly straightforward: by pushing and pulling these components into the addition machine they could repeat additions based on the different lengths of the teeth exposed. It is unclear whether this refers to a mechanism similar to the one in Figure 4 with the label *dentes variabiles*, which had a progressively increasing number of teeth along the length of a cylinder, or whether this was already something looking like the component Leibniz drew in 1695 to represent the machine he had built in Paris twenty-one years earlier in 1674.[14] The lack of contemporary detail about how, when and where the *roue a dents inégales* was developed can be interpreted as negative evidence of the uncredited tacit input that Parisian artisans might have had in the design process.

In any case, by 1673, Leibniz had a concept of the calculator, sketched out some design possibilities and began working on a model with the unnamed Parisian craftsmen.[15] But this was only the beginning of a lifelong tortuous development journey. After 1675, the clockmaker Olivier was supposed to continue the work under

13 Mackensen, op. cit. (6), pp. 143–162. and LH XLII, V, pp. 48–53 and 54–57.

14 Was Leibniz rewriting the history of his own machine? Leibniz mentions the *roue a dents inégales* in the 1677 letter to the Parisian clockmaker Olivier. Cf. Mémoire pour monsieur Olivier touchant la machine perfectionée, LH XLII, 4, II, p. 7. The undated manuscript 'Machina aritmetica qualem curavi elaborarem' seems to be the first comprehensive description of the wheel with unequal teeth. See LH XLII, 4, II, pp. 11–13. This is presented as a correction of and improvement over a previous technology.

15 See letters to Carcavy and correspondence with Ferrand from that year. AA I, 1, p. 452. In January 1673 the so-called *ebauche* was shown to the members of the Royal Society. See Thomas Birch, *The History of the Royal Society*, vol. 2, Hildesheim: Georg Olms, 1968, p. 87. Back in Paris the development work continued while Leibniz was applying for funding from the Académie royale des sciences to bring his idea to the market. See Letter to the Académie, in Mackensen, op. cit. (6), p. 174. By 1675, having exhausted all of his possibilities in Paris, he accepted the position of councilor and librarian to the Duke of Hanover and made his way back to the German states.

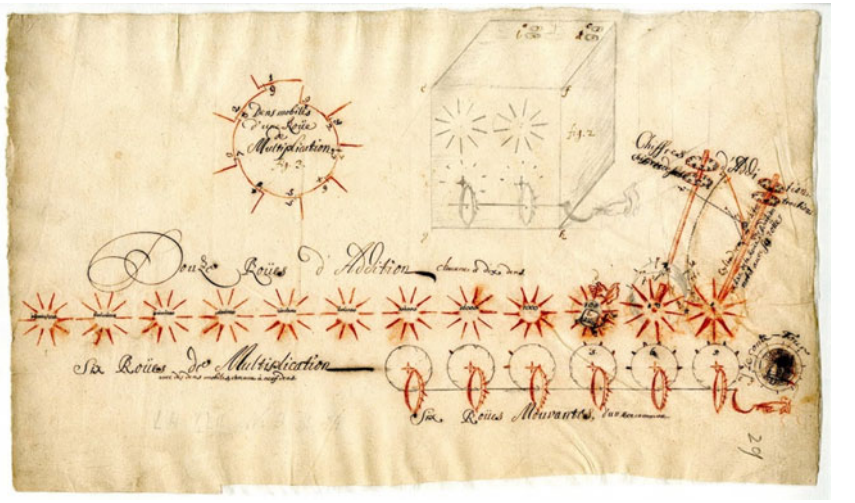

Figure 3. Sketch of the wheel with mobile teeth related to the 1673 project of the machine. LH XLII, 5, p. 29. GWLB Hannover.

the supervision of Adolf Hansen, one of Leibniz's confidantes. But Olivier was in a precarious financial situation and could not dedicate himself fully to the project: he thought it did not pay enough to be worth his time. Close to financial ruin in 1679 he dismantled the newer model of the machine that he was supposed to develop and used the pieces for the clocks he was building for his Parisian clients.[16]

Who exactly did work on the machine after 1679 is unclear, but we know that Leibniz was trying to improve the carrying of decimals – the so-called problem of transports, which threatened to undermine the whole project.[17] Only beginning in 1693 does the picture become clearer. The artisan Georg Heinrich Kölbing was employed. He and the butler Balthasar Ernst Reimers were busying themselves with the machine as Leibniz wanted to present the invention to his patron, Ernst August von Hannover, which he finally managed to do in 1695.[18]

This, however, did not mark the end of the project. The mechanism for carrying tens in the addition component, which Leibniz never managed to fix, would have prevented the reliable display of correct results.[19] From 1696 onward the clockmaker Adam Scherp

16 Hansen's letter of May 1679, AA I, 2, p. 468.

17 Leibniz's manuscripts from this period are mainly focused on this. See, for example, the paper titled 'Machine Arithmetique' 8 Maii 1682, LH XLII, 4, II, p. 40; also 'Ma machine Arithmetique Juinius 1684', LH XLII, 4, II, p. 41.

18 See correspondence with Kölbing, first letter, AA I, 12, N. 65.

19 Leibniz added a pentagonal wheel to each carry to show whether the carry has been correctly performed. See AA I 17, 105. There is speculation that this would have allowed manual intervention to correct errors. See Erwin Stein and Franz Otto Kopp, 'Konstruktion und Theorie der Leibnizschen Rechenmaschinen im Kontext der Vorläufer, Weiterentwicklungen und Nachbauten: Mit einem Überblick zur Geschichte der Zahlensysteme und Rechenhilfsmittel', *Studia Leibnitiana: StL; Zeitschrift für Geschichte der Philosophie und der Wissenschaften* (2010) 42(1), pp. 1–128.

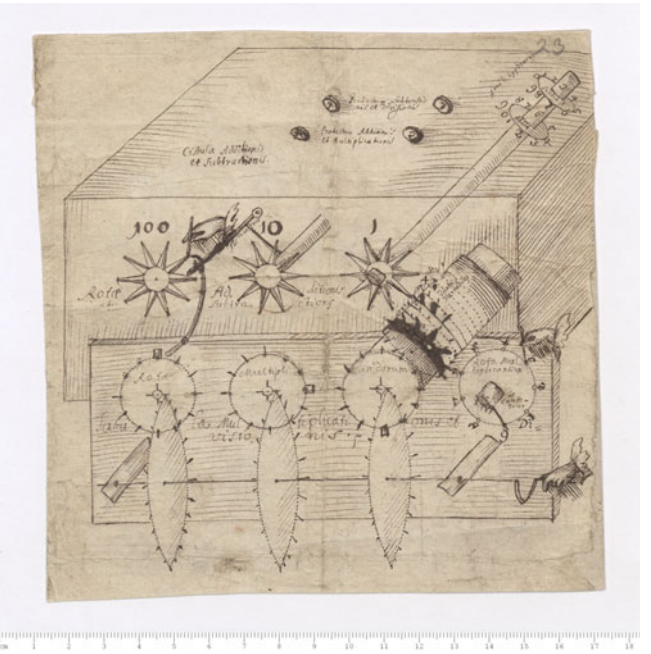

Figure 4. Drawing related to the 1673 project of the machine. LH XLII, 5, p. 23. GWLB Hannover.

had been employed in Hanover to perfect the machine, but in the year 1700, both Scherp and the butler Kölbing having passed away, the decision was made to move it to Helmstedt.[20] Here Christian Wagner, professor at the local university and one of Leibniz's protégés, took up the responsibility to see it completed. Wagner hired the brothers Georg and Levin Warnecke for the job. They were supposed to finally finish the calculator for twelve number places and also start on a third, even bigger, model.

In 1706 the former twelve-place model was taken back to Hanover. Leibniz wanted to present it to Lord Halifax, who came over to negotiate the succession of Georg von Hannover to the throne of England. Apparently the presentation did not go well or did not happen at all. Leibniz soon complained to Wagner about the fact that the instrument did not work as it should. Meanwhile, Levin Warnecke continued work on the larger machine until 1708, when he quit. Wagner then hired the itinerant English clockmaker Keyling. But this employment was short-lived. Keyling soon fled Helmstedt without having payed his loans. He also took with him the all the tools used in Wagner's workshop. In March 1710 the clockmaker Blumenfels was hired, but he too needed to flee Helmstedt. The authorities sought to imprison him because it was thought he was bigamous.[21]

20 AA I, 17, p. 11.

21 The correspondence with Wagner is still largely in manuscript. It was kept at the university of Halle. See Halle UB YG 13; also AA I, 19. Günter Scheel has done research to uncover the names of the artisans who worked on the machine. Scheel, op. cit. (6).

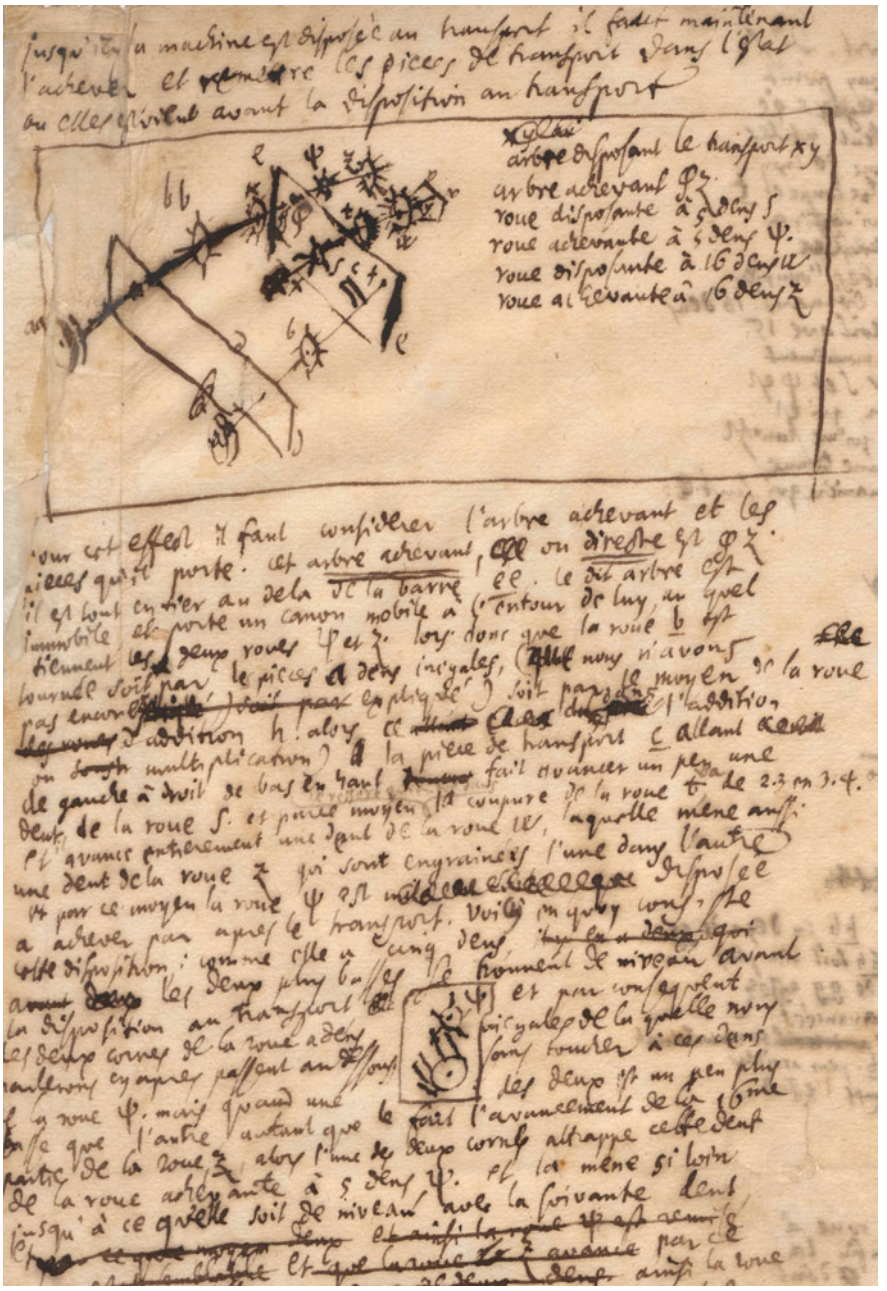

Figure 5. Sketch of the transport and the wheel with unequal teeth from 1674 (drawn in Hanover in 1695). LH XLII, 5, p. 12r. GWLB Hannover.

After 1710, Leibniz took back to Hanover the almost finished, but still not quite working, second machine and the finished pieces of the newly commissioned third machine. In 1712 he entrusted the further development of this third machine to Buchta, councilor at the court of Moritz Wilhelm von Sachsen-Zeiz, and to the court preacher Gottfried Teuber.[22] Leibniz died in 1716 and the project of building the third model of the calculator was never completed. The pieces of the machine remained in Teuber's possession in Zeiz. The second machine for numbers up to twelve places, however, was in Hanover at the time of Leibniz's death, and remained there until 1775, when it travelled yet again, to Göttingen.

Rhetorical devices

Leibniz continued developing his machine until the end of his life and, judging by the many artisans he employed, it must have cost a small fortune. In spite of this, none of the models of the calculator developed during this time worked reliably for other than perhaps very short periods of time on a few set examples.[23] Consistent with the contemporary gentlemanly attitude towards artisans described by Steven Shapin, Leibniz constantly blamed the craftsmen he employed for the failure to 'well execute what was so well conceived'.[24] But he never made his travails known to anyone, except the people he needed for building the machine. In the correspondences with other savants or nobility and in his published account about the calculator from 1710 a radically different picture was presented. Leibniz created for his public a complete rhetorical package centered on the idea of utility. He was promising that his machine would outshine any other invention in the arts and sciences, delivering humanity from the 'servile effort of calculation', cutting in half the difficulty of practising mathematics and making calculation child's play and the work of a student.[25]

22 Three clockmakers were employed there: the two brothers of the mathematician Mathias Has and another unknown artisan. The correspondence sent by Leibniz to Teuber was edited in August Nobbe, *Godofredi Guilielmi L. B. de Leibnitz Lipsiensis Epistolae XLVI*, 1845. For Teuber's letters to Leibiz see manuscripts at the Leibniz library in Hanover, Lbr. 916. The correspondence with Buchta is currently being edited. Some of the transcriptions are available online. See www.gwlb.de/Leibniz/Leibnizarchiv/Veroeffentlichungen/Transkriptionen.htm, accessed 10 February 2014.

23 This can be inferred from the correspondences, Teuber's testimonial and also the more recent replication attempts I discuss bellow. Contrary to what twenty-first-century replicators claim, the functioning replicas with modern materials actually show the limitations of Leibniz's machine at the time it was constructed. Even if the machine had used the manual correcting mechanism, as Stein has argued, it is unclear how well the historical machine would have worked and if it could actually work up to twelve digits as Leibniz claimed.

24 This appears in the correspondence with Teuber explaining the failure to make the carry mechanism work properly: 'Ut decadicarum rotarum translatio bene procedat, necesse est (uti nemo Te iudicare poterit) tam ipsas decadicas rotas, quam fundamentales illas ita aequaliter collocates esse, ut quaevis decadica cuivis fundamentali accomodari posit, quod diligentiam et accurationem in opifice desiderat, et velut lapis est Lydius, quo quid valeat dignosci poterit. Quanto, obsecro, res future esset difficilior; si etiam, ut olim tot aliae particulae, quaevis tot aliis accommodari deberent? Desunt nobis »in Germania« homines satis periti et industrii, qui bene concepta bene exsequantur.' 15 August 1714, Nobbe, op. cit. (22), p. 17. See also Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, Chicago: The University of Chicago Press, 1999, pp. 355–407.

The futuristic discourse about the machine played an important role in Leibniz's political ambitions. In 1671 he was trying to convince Johann Friedrich von Hannover to finance his stay in Paris so that he could persuade Louis XIV to invade the Middle East in order to prevent French forces from attacking other European countries and provoking in this way a 'universal war'. The project of the calculating machine would be used, Leibniz argued, to get access to Colbert, who could give him access to the king.[26] But the German savant did not limit himself to futurespeak. There are many instances where he claimed he had already completed such a wondrous device as he advertised. One example is his letter from March 1673 to Johann Friedrich von Hannover, in which he wrote that his calculator was considered both in Paris and in London as 'one of the greatest inventions of the time' and that 'the greatness of its utility can be easily considered to reach so far as that of Arithmetic itself'.[27] Hungry for a position at the Hanover court, he seems to have stretched the truth to hyperbole. In London, for example, things didn't actually go that well: Robert Hooke gave a scathing evaluation of the first model of the machine in the context of Leibniz's presentation at the Royal Society, writing that what he saw was too complicated to ever be of 'great use, especially common use'.[28] In July 1674 Leibniz again used the present tense to write to Oldenburg, the secretary of the society, that he is relieved to have finished the machine, its effects now universally admired.[29] Oldenburg, in disbelief, rudely called the calculator a 'machinula' in his reply, angrily reminding Leibniz to make good on his promise in front of the society to send over a model, which Leibniz never did.[30]

There are also other instances when people in the know refused to fully accept Leibniz's rhetoric of wondrous utility. The Dutch savant Christiaan Huygens was deferential towards Leibniz and appreciated his efforts to make calculation easier, but in 1675 he let loose, writing about both the calculator and a new machine for extracting the roots of numbers that Leibniz advertised: 'these things are not meant for demonstrating utility, they are more for demonstrating the force of the human mental capacities'.[31]

Leibniz's exchange with Johann Sebastian Haes provides another telling example. Leibniz tried to convince Haes, a councilor for the Landgrave of Cassel, to have his patron buy the calculator. In a letter from January 1695 he wrote to Haes that he had a machine for calculating numbers up to twelve digits. This was based on the model he presented to great acclaim to the Royal Societies of London and Paris. No one had yet seen it, he added, but people from France were already lining up to buy it. Haes wrote

25 A good example is the letter to the Académie des sciences. See Mackensen, op. cit. (6), p. 178; also correspondence with Oldenburg, AA, III, p. 1; and correspondence with Arnauld, Tchirnhaus and Huygens.

26 AA II, 1, 164.

27 AA I, 1, 488.

28 Birch, op. cit. (15), p. 87.

29 AA III, 1, 118–119.

30 'Machinulam Tuam arithmeticam, quam perfecisse Te antehac jam significasti, lubentes equidem lustraremus, si promissi Tui, Soc. Regiae in public congress facti, memor occasione commode transmitter eam velles.' AA, III, I, p. 172. Cf. commentator's note on p. 181 in the volume for the significance of 'machinulam' in this context. He also broke a similar promise to the Académie des sciences in Paris, where he anticipated he would send models of the machine to the Observatoire astronomique and other Parisian institutions.

31 AA III, 1, p. 283.

back asking for more details, his patron being, of course, also interested. Leibniz, thrilled, quickly sent a response. He wrote, upping the ante, that the machine could multiply 654,321 and 99,999 with only five turns of the wheel; that 'the greatest mathematicians of the time admired it after they could see its effects'; and that 'even a child could do everything without knowing any calculation and almost without any concentration of the spirit, speaking and thinking of another thing'. The Jesuit Grimaldi wanted to show it to the 'monarch of China', he added, but unfortunately Leibniz was unable deliver one in time.[32]

Haes stalled until May 1695. He finally wrote back, saying that using Samuel Morland's book on cyclology he had managed all by himself to build a calculating instrument. His new apparatus could operate numbers of more than a hundred million using only one wheel. He conceded abstractly that Leibniz's machine might be superior to those invented by Morland and others, but was not curious to inquire further than its form and size, leaving the offer to buy it completely in the air.[33]

Leibniz did not give an inch publicly to any expressions of doubt. He continued to broadcast his rhetoric about the calculator far and wide. In 1710 he finally took to print, publishing 'Brevis descriptio machinae arithmeticae' in the first issue of the *Miscellanea Berolinensia*.[34] This publication would be the main source of information about the calculator until 1879, when the second model was rediscovered. The 'Brevis descriptio', however, was not exactly informative. Just like the letter to Johann Friedrich, it was a self-promotional account. Leibniz's goal was to get as much recognition as possible while divulging as little as he could about the state of the machine he was actually building. This was meant to discourage both unauthorized copies and unsolicited criticism. As before, the Royal Society; the Académie; and renowned savants such as Huygens, Arnauld and Tschirnhaus were paraded to sustain the wondrous functionality of the calculator 'which even a child could use'. The Pascaline was now completely forgotten as inspiration source – the machine was just *a me adolescente inventa* –invented by Leibniz as a young man. In terms of description of the actual mechanism, things were left vague. Structurally, the calculator is described as consisting of a 'mobile part', an 'immobile part' and 'large and small wheels', and while the operation of multiplication is described adequately as being executed by the addition of the intermediary sums after each multiplication, no details of the internals are disclosed. The engraved image accompanying the text is equally unelucidating: it depicts a closed black box.

The 'Brevis descriptio' was republished in 1727, soon after Leibniz's death, in the *Theatrum Artithmetico-Geometricum* by Jacob Leupold. Leupold was diligent enough to include also the testimonial of Gottfried Teuber, the last man who had worked for Leibniz on this project.[35] Teuber knew very well that Leibniz never produced a fully working machine. He wrote about it in a journal from Leipzig, making note of the fact

32 The relevant letters are at AA III, 6, pp. 271, 278, 305.

33 Leibniz himself had sent the book over to help Haes identify an instrument his patron purchased in England. AA III, 6, p. 368.

34 Gottfried Wilhelm Leibniz, 'Brevis descriptio machinae arithmeticae', *Miscellanea Berolinensia Ad Incrementum Scientiarum* (1710) 1.

35 Jacob Leupold, *Theatrum Arithmetico-Geometricum*, Leipzig: Gleditsch, 1726.

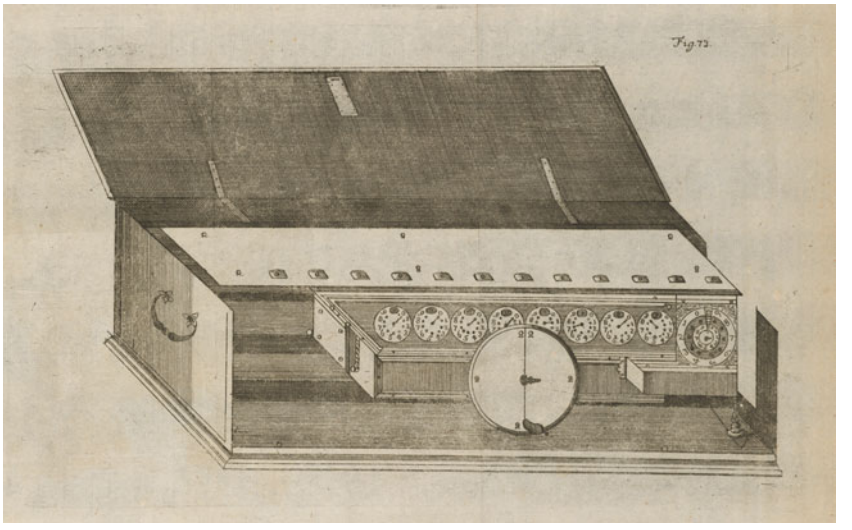

Figure 6. The Leibniz calculator described in the 'Brevis descriptio machinae aritmeticae', *Miscelanea Berolinensia* (1710) 1. Harvard University Libraries.

that because of the high accuracy needed, the second model did not work properly and a third was never finished. In the *Theatrum*, Leupold copied the image from the 'Brevis descriptio' and appended a few drawings that would represent the internal mechanism. These drawings were, however, completely unrelated to the calculator; they actually depict Leupold's own calculating machine.[36]

The second model of Leibniz's machine remained in Hanover until 1775. In this year it was given on loan to the Göttingen mathematician Abraham Gothelf Kästner. Kästner analysed the mechanism and was very disappointed. In the year 1800 he wrote back to Hanover, saying that the machine was a mere relic and he did not believe that it could be of any use.[37] Later, he took his evaluation to print, in the *Fortsetzung der Rechenkunst* of 1801, leaving a clue of where the calculator was located.[38] A few years later, Johann Paul Bischoff, a mechanically interested courtly administrator from Ansbach, also preoccupied himself with the Leibniz machine. In 1804 he wrote, but never published, a history of mechanical calculating machines. Bischoff was well aware of the distance between Leibniz's rhetoric and the actual machine and did not mince his words:

> It may well be that there were some failures in the work on the machine, but I think that it was rather the arrangement of the parts, not the execution, that was responsible, and that the machine could not deliver what Leibniz promised it would do.[39]

36 Matthew Jones interprets this as evidence for emulation. Cf. Jones, *Reckoning with Matter*, op. cit. (6).

37 The letters from Kästner are found together with the manuscripts pertaining to the machine. LH XLII, 4, p. 31r.

38 Abraham Gotthelf Kästner, *Fortsetzung der Rechenkunst in Anwendungen auf mancherley Geschäffte*, Göttingen: Vandenhoeck, 1786, p. 582 f.

39 Johann Paul Bischoff, *Versuch einer Geschichte der Rechenmaschine*, Ansbach, 1804, p. 125.

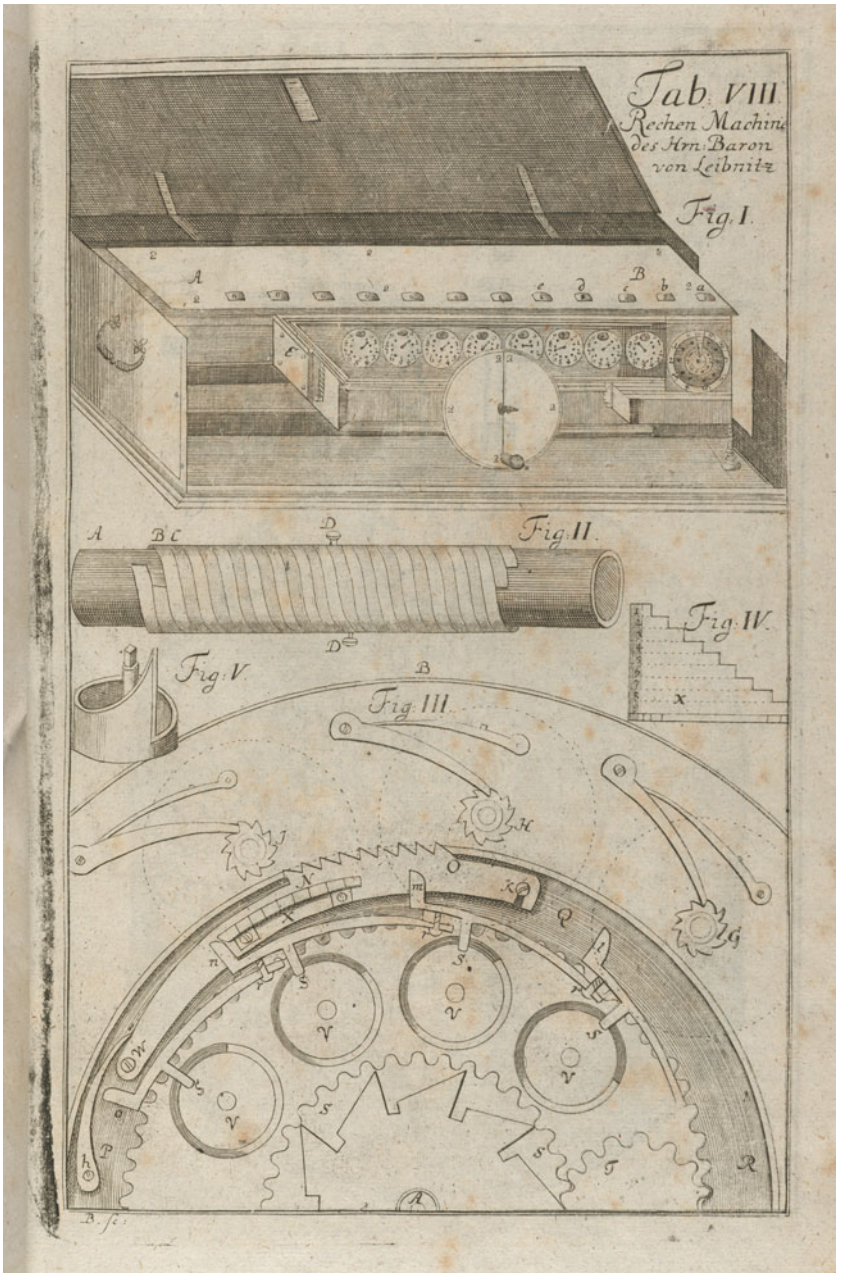

Figure 7. Depiction of the Leibniz machine in Jacob Leupold, *Theatrum Arithmetico-Geometricum*, Leipzig: Gleditsch, 1726. Harvard University Libraries.

Bischoff was also familiar with the calculating machine of Philip Hahn, the first working calculator, which also used a wheel with unequal teeth. But Bischoff never thought that there was any connection between Hahn's machine and Leibniz's.[40] It thus seems that until 1879, at the earliest, nobody knew what the Leibniz calculator actually looked like and what made it work, and those like Kästner who had a clue never described it publicly. Moreover, while the Leibniz machine was recognized as a contribution to the history of mechanical calculation because of the 'Brevis descriptio', there was scepticism about its performance and value. Meanwhile, during the eighteenth and nineteenth centuries, Hahn (1774) and Thomas de Colmar (1820) independently invented mechanical calculating machines, which could function. Both used a wheel with unequal teeth, now called the stepped wheel, as a component. But as Friedrich Kistermann, who researched the influence of the Leibniz machine on later systems, argued, 'it is evident from all we know today that Hahn and de Colmar each invented his own stepped wheel, independent from Leibniz'.[41] Matthew L. Jones has interestingly shown that in spite of the lack of material continuity between Leibniz and later inventors there was still a nexus at the level of discourse, in cases such as Leupold and Hahn: these inventors complemented nescience by suggestions that their projects were emulations of Leibniz's attempt.[42] Beginning in 1879, however, a completely different narrative began to emerge, one focused on material continuity.

Reinventing the Leibniz machine

From 1775, when it entered Kästner's possession, the Leibniz calculator never left Göttingen. In 1879 it was allegedly found in the attic of one of the buildings on the campus of the university, when the roof was being replaced.[43] The rediscovery thrilled beyond imagination the members of the Deutscher Geometerverein – the German Association of Surveyors. Rudolf Gerke, a senior member of the Verein and professor at the Technical University in Hanover, took it upon himself to assess the machine's significance. He reported swiftly to his peers in 1880, his contribution later published in the Verein's journal – the *Zeitschrift für Vermessungswesen*.[44]

Gerke's report has two parts: one historical and one analytical. For the historical part he relied on a certain Dr Mohrmann, a teacher at the *Gymnasium* in Hanover. Mohrman had researched, so he claimed, the relevant documents left by Leibniz and published a history of the machine in two articles appearing in the *Hannoverschen Courier* and the *Weserzeitung*. Gerke was largely in agreement with Mohrmann's findings, appreciating his contribution as a valuable enterprise to be lastingly preserved

40 A drawing of Hahn's stepped wheel is found in Bischoff's book.

41 F.W. Kistermann, 'When Could Anyone Have Seen Leibniz's Stepped Wheel?', *IEEE Annals of the History of Computing* (1999) 21(2), pp. 68–72, 70.

42 Jones, *Reckoning with Matter*, op. cit. (6).

43 Ernst Martin, *The Calculating Machines (Die Rechenmaschinen): Their History and Development*, Cambridge, MA: MIT Press, 1992, p. 41.

44 Rudolf Gerke, 'Die Leibnizsche Rechenmaschine', *Zeitschrift für Vermessungswesen* (1880) 9, pp. 305–312.

for 'correcting the widespread errors about that work of art', which, for him, was the Leibniz calculator.

However, as it appears from Gerke's summary of the articles, Mohrmann actually drafted his revisionist account relying only on Leibniz's public presentation of the machine. In fact, he not only repeated the rhetoric, but also added some embellishments: on the relationship between the calculators of Leibniz and Pascal, Pascals's was of a 'primitive kind', besides which, Leibniz had come up with the idea long before he saw the Pascaline. Even more, the Leibniz machine was so good that everybody was 'filled with amazement', the most important mathematicians of the time 'brought Leibniz their homage' and 'even the friends and relatives of Pascal had to admit the originality of the discovery'.[45]

Building on Mohrmann's inspiring history, Gerke used the second part of his report to propose that Thomas's arithmometer, already very familiar to his readers, was in fact based on the Leibniz machine, being most probably an improvement of the former. Gerke did not exactly have concrete evidence showing when and how Thomas might have learned about the calculator; instead he argued that the structural similarity between the two machines would be enough to sustain his thesis. In order to prove his point, Gerke set, side by side, two images – one of the arithmometer and the other of the calculator. The image of the Leibnizian machine is based on the representation accompanying the 1710 'Brevis descriptio'. The comparative logic also follows this publication. Yes, admits Gerke, 'Thomas had replaced, relative to Leibniz's machine, the "mobile part" with the "immobile" and the round wheels with vertical openings', but these 'small improvements' could easily be implemented. The similarities between the two machines are 'too obvious' and imply that Thomas must have known about the calculator, the latter being 'the originator of all later mechanical calculators using the stepped-drum principle'.[46]

For the members of the Geometerverein, Gerke's thesis was too good not to be true, especially since, at the time, German manufacturers, such as Arthur Burkhardt, were producing clones of the commercially successful Thomas machine for the German and international markets. In this context, it was better to think of the arithmometer as something originally German, finally returned home after a trip to France, than entertain the notion that the Germans were selling imitations of a French invention, which was politically problematic in the wake of the Franco-Prussian war of 1870. Nobody, therefore, had an interest in scrutinizing Gerke's report. The celebrated Hanover geodesist Wilhelm Jordan further bolstered his account, repeating the analogy thesis in his own publications about the machine and also in his authoritative *Handbuch der Vermessungskunde* (Handbook of Surveying), which became the standard work in the field well into the twentieth century. Here, in the chapter dedicated to calculating

45 Translation of the passage in full: 'The thing was so well built that according to Leibniz and the testimony of other mathematicians, even a child could calculate with the machine. The whole world was filled with wonder over the invention. The great mathematicians such as Huygens, Thevenot, Arnaud and others paid Leibniz their homage and even the friends and relatives of Pascal had to admit the originality of the invention.' Gerke, op. cit. (44), p. 307.

46 Gerke, op. cit. (44), pp. 310–311.

Figure 8. Burkhardt's clone of the arithmometer. From Wilhelm Jordan, *Handbuch der Vermessungskunde*, Stuttgart: Metzler, 1895, p. 162. Harvard University Libraries.

technology, he writes, 'The calculating machine, which is essentially an invention of the philosopher Leibniz, was built in the form it is used today by Thomas in Colmar and is now produced industrially in Germany by Arthur Burkhardt in Glashütte, Saxony.'[47] Like Gerke he also uses elements from the 'Brevis descriptio' to make analogies with the arithmometer:

> The small round wheels on the mobile part [in Leibniz's machine] correspond to the vertical openings with the buttons you can push up and down. The openings on the immobile part correspond to the openings on the mobile part of Burkhardt's machine. The reciprocal mobility goes for Leibniz in the reverse direction in comparison with Burkhardt, which is unessential, because it concerns only the relative movement.[48]

Jordan was so convinced that the Leibniz calculator used to be a working arithmometer that he advised Eduard Bodemann, who was in charge of the Royal Library in Hanover, to send it to Burkhardt, who, he believed, was uniquely positioned to restore it to its former glory; he was, after all, manufacturing the German version of Thomas's machine. Burkhardt's refurbishing job was deemed important as a way to secure Germany's priority over France with respect to calculating technology. As Jordan clearly stated, the goal was the 'safeguarding of the principle of the stepped-wheel calculating machine as an invention of the German philosopher from the end of the seventeenth century, after, for a long time, a non-German invention at the beginning of this century was given credit'.[49]

47 Wilhelm Jordan, *Handbuch der Vermessungskunde*, Stuttgart: Metzler, 1895, p. 136.

48 Jordan, op. cit. (47), p. 137.

49 Jordan's note at the end of Burkhardt's report. See A. Burkhardt, 'Die Leibnizsche Rechenmaschine', *Zeitschrift für Vermessungswesen* (1897) 26, pp. 392–398, 398.

Burkhardt's restoration

Arthur Burkhardt premised his restoration of the calculator on the account in the 'Brevis descriptio', made popular again by Mohrman and Gerke. He was naturally expecting to see the childproof machine of which so many had sung the praises. But the instrument he found strongly refuted his expectations: 'all the gears and discs fell toward me – they were merely stored in the box and in the frame'. Initially placing the blame on wear and tear, he tried to reconstruct the mechanism, as he believed it should have been. Heavy modifications are thus documented in his report. For example, gears that he found to have been only cast, never adjusted, as they were probably never used, were newly ground down by 2.5 millimetres to fit better. The original metal axes, considered of a 'dubious nature', were straightened, and he installed 'round rings which I made so that they remain fixed, as if united with the axes, and I fitted them in their place with the help of small screws'. The frame was taken apart, being found crooked, and dealt a series of hammer blows:

> It had to take a lot of blows with the hammer, a couple of holes were drilled into it, then polished, and again closed, drilled again, polished and so on. Its surface is a testament to an entire history of the person who, so to speak, understands its language and learned how to understand its language.[50]

In spite of all these efforts, when put together, the machine still did not seem to live up to Leibniz's rhetoric. It simply didn't do anything. At this point, in need of something less dramatic, Burkhardt fell back on the arithmometer theory. In an arithmometer the angle distance between the teeth of the stepped drum is a measurement of the execution of an intermediary operation – this is called a tempus. In this framework, the Leibniz machine appears to have insufficient tempi: 360 degrees are necessary, but it only has 315 degrees (14×22.5 for each drum.) In order to work properly, the machine would have needed, according to Burkhardt, to compensate for the difference. To reach this goal, new adjustments and alterations were necessary. But even after this painstaking effort the calculator still did not seem to function properly. Finally he threw in the towel:

> From these considerations we must reach the conclusion that Leibniz's calculating machine present here is, in what concerns its elements, ingeniously constructed and executed. But that in his time Leibniz must have been living with the belief that just by arranging together such elements any machine would provide results. Only in this way one can explain the way it is put together at present. From this, we must follow, that the present machine could never have been working.[51]

But Burkhardt was not intending to rob Leibniz of his newly fashioned computing greatness. He quickly found some mitigating circumstances: the instrument, with which even a child could easily do mathematical operations, 'must have been another one, of another construction'. Besides, even this non-functioning device, he writes, 'confirms the belief that Leibniz was the constructor and initiator of the first calculator and with this he set the foundation for all calculating machines'.[52]

50 Burkhardt, op. cit. (49), p. 395.
51 Burkhardt, op. cit. (49), p. 398.

Figure 9. Brunsviga advertisement from 1936. Harvard University Libraries.

Burkhardt's reconstruction was an earnest effort to mechanically embody the new interpretative context that the calculator was cast in after 1879. The mechanical ensemble found in Göttingen was remade to bring back to life the Leibnizian machine described in the 'Brevis descriptio', a machine now believed to be an earlier version of Thomas's arithmometer as per Gerke's and Jordan's reading. Burkhardt's report is ultimately a compelling document. It shows that the rewriting of history is not just limited to text; it can be embodied in metal and wood, becoming material rewriting.

It works after all: replicas of the calculator

Burkhardt's material rewriting of history was, however, only the first in a series. The restored artefact, the newly made hybrid machine, was returned to Hanover. Because of its fragility and, perhaps, its underwhelming performance, it was kept under lock and key. But at the beginning of the twentieth century, because of the ballooning public interest in calculation, the making of copies was allowed. Some of these replicas, like the 1925 models built by the computing company Brunsviga, were meant not only to enhance the post-mortem status of Leibniz, but also to project back a tradition. The company IBM purchased one of these models and incorporated it in a permanent exhibit about the evolution of the computer. The catalogue entry informs us that while the Leibniz machine was not developed for commercial production, 'the stepped drum principle survived for 300 years and was used in many later calculating systems'.[53]

Animated by such exhortations, later projects to replicate the calculator went even further. The competing projects of the mathematician Nikolaus Lehmann from 1989

52 Burkhardt, op. cit. (49), p. 393.
53 See www-03.ibm.com/ibm/history/exhibits/attic3/attic3_037.html, accessed 11 February 2014.

and the engineer Klaus Badur from 2004 are relevant here.[54] Their ambition was to prove that the calculator was not merely a source of computing ideas, which was by now widely accepted, but an actually functioning instrument. These projects added yet another layer of the rewriting of history to the saga of the calculator.

Take Lehmann's account, for instance. His project's aim was explicitly 'to finally resolve all the contradictory statements about the functionality of the calculator'.[55] If he showed that the machine worked we would know it could have always worked. Lehmann's foil in this sense is none other than Burkhardt. Burkhardt, according to Lehmann, had used a 'false theory' to reconstruct the machine. A true theory would be one that produced an actually working machine.[56] Only this kind of machine could be considered 'true to the original', and it only would completely correspond to 'Leibniz's intentions'.[57] These intentions, now realized in Lehmann's own replica, demonstrate that Leibniz 'practically discovered already in that time all the solutions that were later implemented with success in the 250-year history of calculating technology'.[58] There is no escape from this logic: a non-working machine would simply be rejected as being below Leibniz's dignity.

Klaus Badur's 2004 replication project, in collaboration with the engineer Wolfgang Rottstedt, is premised on the same argumentative structure.[59] Interestingly, however, this time Lehmann, not Burkhardt, is accused of being the falsifier and his effort dismissed as inauthentic: Lehmann had changed things such as the dimensions of the machine and even individual components, doing everything possible to have the

54 In addition to these two projects there is a third by Erwin Stein. It does not differ substantially, however, from Badur's and Lehmann's, being also an attempt to show that the machine worked 'after all'. See Franz Otto Kopp and Erwin Stein, 'Es funktioniert doch – mit zwei Korrekturen: Zehnerüberträge der Leibniz-Maschine; zur Konstruktion des hannoverschen Nachbaus der Vier-Spezies-Rechenmaschine von Leibniz', *Leibniz: Auf den Spuren des großen DenkersUnimagazin* (2006) 3–4, pp. 56–59; Kopp and Stein, 'Konstruktive Verbesserungen im hannoverschen Modell der Leibnizschen Vier-Spezies-Rechenmaschine', *Einheit in der Vielheit*, Teil 1, Hannover: Gottfried-Wilhelm-Leibniz-Ges, 2006, pp. 390–397; Erwin Stein and Franz Otto Kopp, 'Calculemus! Neue hannoversche Funktionsmodelle zu den Rechenmaschinen von Leibniz', *Leibniz: auf den Spuren des großen DenkersUnimagazin* (2006) 3–4, pp. 60–63. The description of another reconstruction of a Leibniz cypher machine can be found in Nicholas Rescher, *Leibniz and Cryptography: An Account on the Occasion of the Initial Exhibition of the Reconstruction of Leibniz's Cipher Machine*, Pittsburgh, PA: University Library System, University of Pittsburgh, 2012.

55 Nikolaus Joachim Lehmann, 'Leibniz als Erfinder und Konstrukteur von Rechenmaschinen', in Kurt Nowak and Hans Power (eds.), *Wissenschaft und Weltgestaltung*, Hildesheim, 1999, pp. 255–267.

56 The passage in full: 'While the construction of the Dresden replica was progressing its functionality was studied in greater detail and it was recognized that the basic measurements and order of the parts allowed for the fully automatic carry of the decimals, which Leibniz wanted. Burkhardt followed in his restoration a theory that was based on false assumptions and wrongly modified the machine according to it.' Lehmann, op. cit. (55), p. 176.

57 The passage in full reads, 'The Dresden replica, which is capable of functioning and accords perfectly with Leibniz's intention, confirms perfectly the feasibility of his conception and also his ideas in great detail.' Lehmann, op. cit. (55), p. 186.

58 Lehmann, op. cit. (55), p. 188.

59 Klaus Badur and Wolfgang Rottstedt, 'Und sie rechnet doch richtig! Erfahrungen beim Nachbau einer Leibniz-Rechenmaschine', *Studia Leibnitiana* (2004) 36, pp. 130–146; Klaus Badur, 'Neue Erkenntnisse zur Rechengenauigkeit der Leibniz Rechenmaschine: Erfahrungen mit einem originalgetreuen Nachbau', in *Einheit in der Vielheit*, Vorträge, VIII, Hannover: Gottfried-Wilhelm-Leibniz-Ges, 2006, pp. 16–23.

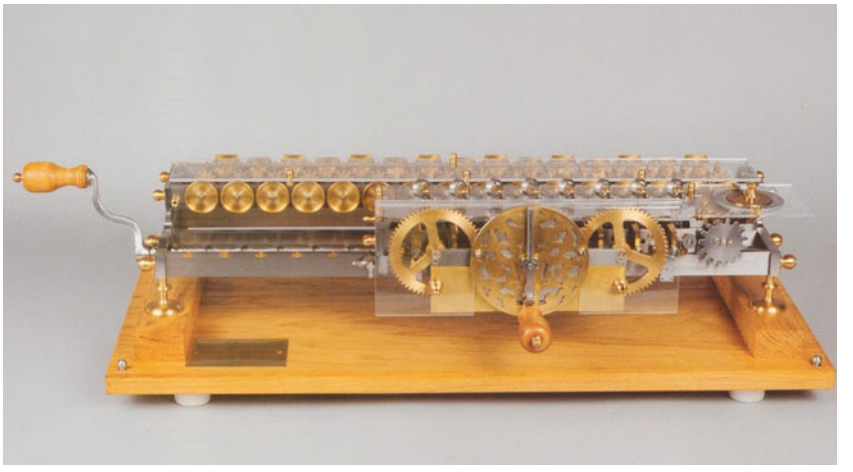

Figure 10. The Badur replica. GWLB Hannover.

ensemble function correctly.[60] While he, Badur, was also interested in showing that the machine worked, only a real 'true-to-the-original' copy would be compelling enough to make a historical statement about functionality. The crux of Badur's authenticity argument lies in the fact that he copied the machine according to the 'original dimensions', taking as his model the artefact from Hanover, understood as the product of Leibniz's own hand.[61] Care for authenticity is given airing at every step of the way, but there are occasional slips: the materials used were modern alloys, and they applied modern finishing techniques to ensure a precision of one-hundredth of a millimetre in making the difficult mechanism for carrying tens. The use of this kind precision, as Badur argues, is not a bug, but a feature of the project: while it does perhaps show that the calculator might not have worked in the past, this is taken to mean that 'Leibniz was ahead of his time, relative to the implementation possibilities'.[62] It follows that if he had had those possibilities then he would surely have made something like the functioning replica. The machine, Badur concludes, indeed functions after all – 'Und sie rechnet doch richtig!'

Looking underneath these claims, we find that just as for experimental replication we also have here a case of what Harry Collins called the experimenter's regress:[63] the

60 Cf. Badur, op. cit. (59), 19.

61 He refers to the machine as an 'original true replica with modern finishing techniques' – 'originalgetreue Nachbau mit moderner Fertigungstechnik'. Badur, op. cit. (59), 20.

62 The entire passage reads: 'In conclusion I want to say that Leibniz was right when he wrote in his letter to Johann Bernouli on 26 May 1697 that he has a clear idea of the internal construction of the machine and that the perfection of the machine will depend only on the good implementation of his ideas. To this I want to add that the technical possibilities were not given at that time. Leibniz was ahead of his time with his ideas, relative to the implementation possibilities.' Badur, op. cit. (59), 20.

63 H.M. Collins, *Changing Order: Replication and Induction in Scientific Practice*, London: Sage Publications, 1985.

outcome of replication changes the very criteria by which we assess truth and falsehood, in this situation historical truth and historical falsehood. The 'replication' of a working calculator casts a shadow of doubt over any other non-working one; the one true to the original seems to completely substitute any other original, even one that Leibniz actually built. In this way we come full circle: Lehmann and Badur finally managed to write for the Leibniz calculator 'a future of a past that never happened'. Leibniz consequently finally managed to build in the twenty-first century the machine he had boasted about in the seventeenth.

Conclusion: when ghost ships get into museum bottles

On 30 September 2009, the office for public relations of the Gottfried Wilhelm Leibniz Library in Hanover released a statement to the press with the title 'Leibniz in Washington'. It begins with the following words: 'Gottfried Wilhelm Leibniz will also be present in Washington at the reception for 3,000 guests organized by the government of Lower Saxony and the German embassy on 2 October 2009'. The return of the living dead? No, the text is quick to reassure, the statue of Leibniz will be there, not the real person, as will, most importantly, it is poignantly emphasized, the original true copy of the calculating machine. The statement closes with a quote from the MP for Lower Saxony:

> I am happy that, in this way, Leibniz will be present there as an ambassador of a science which is innovative and friendly towards human beings and as an ambassador of Lower Saxony. He is one of the greatest geniuses that lived and worked on the territory of today's Lower Saxony.[64]

As the mixing of past and present in the pronouncement of the MP suggests, in our global cultural–political imagination, Leibniz thus appears to be less than ever the Leibniz of the calculus controversy with Newton, the Leibniz of the philosophy of possible worlds or the Leibniz of the Theodicy. The essence of everything Leibniz accomplished, and that which makes him one of the 'greatest geniuses', is condensed in this single ambassadorial invention – the calculating machine. This seems to be now our emblem for Leibniz, just as the telescope is the emblem for Galileo, Boyle's law for Robert Boyle, gravity for Isaac Newton and $e = mc^2$ for Albert Einstein.

The goal of this paper has been to open up this problem of emblems. How did we get to believe what we believe about the figures from the past in terms of the stories of discovery we tell about them? This is the question I tried to address here and I focused particularly on the role of artefacts. I showed how the Leibniz machine, now commonly seen as a major breakthrough, was reinvented as such only beginning in 1879, in a context where, out of a nationalistic impulse, the members of the German Society of Surveyors tried to secure the priority of Leibniz over the Frenchman Thomas de Colmar as the inventor of the stepped-drum calculator. Subsequently, as I have shown, this

64 See www.nlb-hannover.de/kulturprogramm/pressemitteilungen/2009/Washington.pdf, accessed 11 February 2014.

narrative was piled on and deepened in the twentieth century by computing companies such as Brunsviga and IBM and by replication projects aimed at showing that it actually worked 'after all'.

There are two further aspects that merit discussion in view of this narrative of reinvention. First, the status of the claim repeated ad nauseam in current standard histories of computing that Leibniz was the discoverer of 'the principle of the stepped-drum calculating machine'. This notion, as I hope to have shown here, is a way of thinking about the calculator that appeared only after 1879. Leibniz never saw himself as the discoverer of any principle of calculation. The *roue a dents inégales* was a development arising most probably from a context of collaboration with Parisian clockmakers and mechanics. More research is needed on this topic, but it is not unlikely that similarly shaped components were parts of clocks, music boxes or other mechanical devices of the time, something present in an already existing pool of technological knowledge that a skilled artisan would have quickly grasped.[65] Moreover, the phrase 'stepped drum', *Staffelwalzen* in German, was only coined after Thomas's arithmometer was invented and became popular. This word is a way of summarizing neatly in English and German what French commentators described longwindedly as having 'the appearance of a staircase with short steps surrounding a column'.[66] Based on contemporary accounts of the arithmometer, Thomas invented the component by trial and error, just like the other aspects of his machine.[67] Initially it was not even considered an important development, being overshadowed by Thomas's successful mechanism for carrying tens (one of the points where Leibniz had failed), which made his machine functional and commercially viable.[68] It is in fact very likely that it was only after the German surveyors pushed the narrative of Leibniz's priority that the stepped wheel became important as an identifier of the Thomas machine in the first place. The Leibniz calculator is even occasionally called 'the stepped reckoner' to further emphasize the importance of this item. The narrative of the stepped drum's centrality has become so successful that accounts of the arithmometer now often contain the fact that it is based on a technology invented by Leibniz.[69] In a 'back-to-the-future' kind of way, this idea is now being used to enhance the status of the arithmometer, putting the engineer Thomas in the league of philosopher–polymaths such as Leibniz.

Beyond this, the case of the reinvention of the Leibniz machine also raises interesting questions about the way we talk about the past. The genius narratives long suspected

65 Mackensen, op.cit. (6), p. 44, suggests an analogy with a music box set-up depicted in Athanasius Kirchner's *Musurgia universalis*.

66 M. Hoyau, 'Description d'une machine à calculer nommée arithmomètre, de l'invention de M. Le Chevalier Thomas, de Colmar', in *Bulletin de la Société d'encouragement pour l'industrie nationale*, Paris: Siège de la Société, 1822, pp. 356–368, 357 – 'l'aspect d'un escalier à marches très courtes, tournant autour d'une colonne'.

67 Hoyau, op. cit. (66). See also other documents available online at www.arithmometre.org/Bibliotheque/PageBibliothequeA.html, accessed 11 February 2014.

68 See how the machine is presented in *Archives des découvertes et des inventions nouvelles*, Paris: Treuttel et Würtz, 1823, 279.

69 For example See *Encyclopedia Britannica*, at www.britannica.com/EBchecked/topic/726021/Arithmometer, accessed 11 February 2014.

and critiqued by historians and academics at large are alive and well. They are very much a tool of public memory and remembrance, being constantly used to reawaken interest in the figures of old. But is this tool achieving its goal? In an age of widespread use of parody and irony, can stiff, monumental stories still inspire and entice? Isn't the public ready, perhaps readier than ever, to stomach the messiness and complexity of the past and live out the realization that the canonical figures of ages long gone were actually people of their time? These are questions that merit deeper consideration and analysis by historians of science and others.